Computational Modeling and Design Optimization of Structures using the Phase Field Fracture Method

Haim Waisman

Columbia University, USA

The phase field fracture method has been widely adopted due to its ability to handle crack initiation/propagation, and complex crack topologies without the need for explicit tracking fracture surfaces. I will discuss several applications related to fracture modeling and design optimization of structures which relies on the phase field method.

The first part of the presentation will focus on dynamic fracture of metals that often result in brittle and/or ductile fracture, depending on loading rates, geometry and material type. Further, at high strain rates, a material instability known as shear banding, may also occur and lead to narrow localization bands which reduce the stress bearing capacity of the material. I will present a model that can simultaneously account for these two failure processes through a novel phase-field formulation coupled to a temperature-dependent viscoplasticity for shear bands. I will also propose a material stability analysis to determine the onset of localization, which can be employed for adaptive mesh refinement.

The second part of the talk will be devoted to optimal design of structures for enhanced fracture resistance. I will present two topology optimization formulations, in which low weight designs are achieved with substantially increased fracture resistance. In contrast to the majority of the current relevant literature which favors stress constraints with linear elastic physics, we explicitly simulate brittle fracture using the phase field method during the topology optimization procedure. Subsequently, design for ductile failure and buckling resistance is addressed through an efficient numerical approach. The optimized structures are also subjected to a post-optimization verification step which show significant gains in structural strength and toughness.